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Original Study

# High Intake of Nonmilk Extrinsic Sugars Is Associated With Protein and Micronutrient Dilution in Home-Dwelling and Institutionalized Older People

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A B S T R A C T

*Background:* High dietary sugar intake may compromise protein and micronutrient intakes in people with low energy intakes. The results of micronutrient dilution studies in older people have been few and conflicting. We examined the nutritional status and nutrient intakes associated with nonmilk extrinsic sugars (NMES) intakes in older people representing a broad spectrum of both healthy and vulnerable older populations.

*Design and participants:* This cross-sectional study combined five Finnish data sets covering home-dwelling (n = 526) and institutionalized (n = 374) older people. Their nutritional status was assessed using Mini Nutritional Assessment (MNA) and nutrient intakes retrieved from 1- to 3-day food records. The participants were divided into quartiles corresponding to the proportions of energy received from NMES. Energy, nutrient, and fiber intakes were classified according to the NMES quartiles, and the participants were divided according to their places of residence (home, institution).

*Results:* High NMES intakes were associated with older age, female sex, poor cognition, low MNA scores, immobility, and institutionalization. In all, 90% of the participants in the highest NMES quartile (Q4) were institutionalized. In the institutionalized individuals, low protein and micronutrient intakes were observed in both those with low energy intake (Q1) and in those with very high NMES intakes (Q4). In home-dwelling individuals, the nutrient intakes tended to decline linearly with increasing NMES intakes in protein and most micronutrients.

*Conclusions:* Institutionalized older people consumed diets high in NMES, compared with those living at home, and their low energy and high NMES intakes were associated with low protein and micronutrient intakes.



High dietary sugar intake may have detrimental health effects and has been associated with increased dental caries, cardiovascular risk, and obesity.[1] Older people's nutritional risks differ from those of younger individuals, and the effects of their sugar intake have not been thoroughly examined.[2] Few studies have suggested micronutrient dilution in association with high sugar intakes in older individuals, but the results have been few and conflicting.[3] In older South African women and older Australians, micronutrient dilution was observed in association with diets high in added sugars.[4,5] In contrast, moderately high intakes of nonmilk extrinsic sugars (NMES) were not associated with micronutrient intakes in independent older people.[6] Furthermore, in younger people micronutrient dilution in association with total sugar intake has not been observed, although poor diet quality and lower nutrient intakes have been associated with diets high in added sugars.[3,7,8]

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The authors declare no conflicts of interest.

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The objective of this study was to determine how NMES intake affects protein, other nutrient, and fiber intakes in older people representing a wide spectrum of older populations, from healthy home-dwelling individuals to those in institutions, and to determine the factors associated with high NMES intake in older people.

## Methods

Our cross-sectional study combined five Finnish data sets of studies of older individuals (n = 900). The participants came from the following studies: (1) nutrition education and cooking (NC) class (n = 54) follow-up study[9]; (2) men from the Helsinki Businessmen Study (HBS) (n = 68)[10]; (3) home-dwelling individuals with Alzheimer disease (AD) (n = 99); and (4) their spousal caregivers (CGs) (n = 97)[11]; (5) people screened for the Porvoo Sarcopenia and Nutrition Trial (PSNT) (n = 208)[12]; and (6) residents of assisted living facilities (ALFs) from the Helsinki metropolitan area (n = 374).[13] People younger than 60 years were excluded from the data analysis. The NC participants were healthy volunteers interested in nutrition- and health-related issues. The baseline findings of the study were used. The HBS longitudinal cohort included independently living men from the highest social class. The data used were from their most recent visit to the clinic in 2011. Home-dwelling AD patients and their spousal CGs participated in a study with the objective of supporting their nutrition by tailored nutritional counseling. The baseline data were used in this study. The PSNT was a trial investigating the effects of protein supplementation and home-based exercises on physical performance among home-dwelling people at risk of sarcopenia. We used the initial screening data of the study. The ALF participants were residents in the Helsinki metropolitan area. ALFs in Finland are similar to nursing homes, with round-the-clock care available, but in a more homelike setting. The recruitment and eligibility of the participants in each study were reported elsewhere.[9–13]

Nutritional status was assessed with the Mini Nutritional Assessment (MNA).[14] The nutritional intakes were retrieved from 1- to 3-day food diaries, which the participants filled in themselves (NC, HBS, CG, PSNT) or had someone fill in the diaries for them (AD, ALF). The food diaries were checked and verified by a nutritionist in face-to-face interviews (NC) or by phone calls (CG, AD, PSNT, HBS). The ALF residents' dietary intakes were recorded by trained nurses. The nutrient intakes were calculated using the Nutrica 3.1122 or Aivo programs developed for this purpose.[15,16]

Cognition was measured using the Clinical Dementia Rating (CDR) scale (0-3), in which 0 denotes no dementia, 0.5 possible dementia, 1 mild, 2 moderate, and 3 severe dementia.[17] The Charlson Comorbidity Index (CCI) (range 0-9) was calculated from reported diagnoses (NC, CG, AD, HBS) or from diagnoses verified from their medical records (PSNT, ALF).[18] The mobility of the participants was measured using the MNA's three-scale mobility question (0 = bed- or chairbound, 1 = able to get out of bed/chair, does not go out, or 2 = goes out).

The percentage of dietary energy (E%) received from NMES was calculated for each participant. The participants were then classified into quartiles corresponding to the E% received from NMES. The energy, nutrient, and fiber intakes were classified according to the NMES quartiles, and the participants were divided according to their place of residence (home, institution). The relationships between the NMES quartiles for energy, nutrient, and fiber were analyzed using the generalized linear model by analysis of variance (ANOVA) adjusted with weight and age when appropriate. Interaction was tested between the energy and nutrient intakes, place of residence, and E% received from NMES.

The percentage of participants in each NMES quartile receiving inadequate amounts of micronutrients, defined as intake values below the average requirement (AR), were calculated and the differences between the quartiles analyzed using the chi-square test for evaluating the differences between other groups with categorical variables.[19] The statistical analysis was performed using the SPSS statistical program, version 22 (IBM Corp, Armonk, NY), and Stata (release 13.1; StataCorp LP, College Station, TX).

### *Ethics*

All participants signed an informed consent or, in case of poor capability of judgment, MMSE <20, or CDR memory item >1, the consent was acquired from the closest proxy. All of the study protocols were approved by the Ethics Committee of Human Sciences of the

**Table 1**
Baseline Characteristics According to the NMES Intake Quartiles

| Baseline Characteristics | NMES Intake Quartiles | | | | *P* Value* |
|---|---|---|---|---|---|
| | Q1 NMES, Mean 5 (0–6.9) E% (n = 225) | Q2 NMES, Mean 8 (7–9.7) E% (n = 225) | Q3 NMES, Mean 12 (9.8–15.1) E% (n = 225) | Q4 NMES, Mean 21 (15.2–38) E% (n = 225) | |
| Age, mean years | 79 (7.6) | 79.3 (7.3) | 81.9 (6.5) | 83.8 (7.2) | <.001 |
| Sex, % | | | | | <.001 |
| Males | 47 | 42 | 29 | 20 | |
| Females | 53 | 58 | 71 | 80 | |
| Place of residence, % | | | | | <.001 |
| Home | 91 | 80 | 52 | 10 | |
| Institution | 9 | 20 | 48 | 90 | |
| Mobility | | | | | <.001 |
| Bed-/chairbound or does not go out | 5 | 11 | 30 | 58 | |
| Goes out | 95 | 89 | 70 | 42 | |
| BMI | 26.5 (4.2) | 26.8 (4.9) | 26.1 (4.4) | 24.5 (4.5) | <.001 |
| MNA | 23.8 (3.2) | 23.7 (3.3) | 22.5 (3.3) | 20.1 (3.8) | <.001 |
| CCI | 2.1 (1.8) | 2.0 (1.6) | 2.0 (1.5) | 2.2 (1.4) | .41 |
| CDR, % | | | | | <.001 |
| 0 = no dementia | 57 | 39 | 22 | 8 | |
| 0.5–1.0 = possible or mild | 25 | 30 | 25 | 22 | |
| 2–3 = moderate or severe dementia | 18 | 31 | 54 | 71 | |

BMI, body mass index; CCI, Charlson Comorbidity Index[18]; CDR, Clinical dementia rating[17]; MNA, Mini Nutritional Assessment[14]; NMES, nonmilk extrinct sugars; Q, quartile.
*Statistical significance for the hypotheses of linearity was evaluated by analysis of variance (ANOVA). Differences between the groups for categorical variables were tested with the chi-square test or Fisher exact test.

**Table 2**
Dietary Energy, Protein, Carbohydrate, Fat, and Micronutrient Intakes According to the NMES Intake Quartiles

| Dietary Intake | NMES Quartiles Home-Dwelling Older People (n = 526) | | | | *P* Value* | NMES Quartiles Institutionalized Older People (n = 374) | | | | *P* Value* | *P* Values† | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 (n = 205) | Q2 (n = 181) | Q3 (n = 118) | Q4 (n = 22) | | Q1 (n = 20) | Q2 (n = 44) | Q3 (n = 107) | Q4 (n = 203) | | Place | NMES | Interaction |
| Energy, kcal | 1624 | 1714 | 1683 | 1629 | .312 | 1314 | 1717 | 1725 | 1705 | .023 | .525 | <.001 | .008 |
| Energy from NMES, kcal | 79 | 142 | 193 | 296 | <.001 | 63 | 144 | 218 | 354 | <.001 | <.001 | <.001 | <.001 |
| Protein, g | 75.8 | 74.3 | 66.7 | 61.3 | <.001 | 54.8 | 66.1 | 66.9 | 58.5 | .073 | .021 | .099 | .001 |
| g/BW kg/d | 1.06 | 1.02 | 0.95 | 0.87 | .001 | 0.81 | 1.0 | 1.06 | 0.96 | .876 | .526 | .165 | .002 |
| Carbohydrates total, g | 168.1 | 193.5 | 199.2 | 220.1 | <.001 | 144.9 | 199.2 | 215.0 | 239.0 | <.001 | .013 | <.001 | .025 |
| NMES, g | 19.7 | 35.6 | 48.3 | 73.9 | <.001 | 15.7 | 35.9 | 54.4 | 88.4 | <.001 | <.001 | <.001 | <.001 |
| Fiber, g | 20.8 | 21.4 | 19.5 | 17.3 | .042 | 13.8 | 16.7 | 16.0 | 14.0 | .023 | <.001 | .017 | .221 |
| Fat, total, g | 66.9 | 66.7 | 64.3 | 52.4 | .040 | 55.5 | 68.6 | 63.7 | 54.0 | <.001 | .919 | <.001 | .168 |
| SFA, g | 25.7 | 26.3 | 26.1 | 22.4 | .674 | 23.0 | 28.5 | 25.8 | 22.8 | .007 | .456 | .003 | .320 |
| MUFA, g | 19.1 | 17.8 | 15.9 | 12.7 | .002 | 17.2 | 21.9 | 20.4 | 16.4 | <.001 | <.001 | .012 | .085 |
| PUFA, g | 15.2 | 15.6 | 15.7 | 11.7 | .598 | 7.2 | 8.3 | 8.3 | 7.1 | <.001 | <.001 | .001 | .569 |
| Vitamin A, μg | 1170 | 1086 | 842 | 1074 | .039 | 709 | 828 | 951 | 633 | .305 | .066 | .958 | .211 |
| Vitamin D, μg | 11.2 | 11.3 | 9.0 | 6.7 | .002 | 6.0 | 7.4 | 7.7 | 6.3 | .230 | <.001 | .028 | .029 |
| Vitamin E, mg | 9.8 | 9.9 | 9.3 | 7.7 | .098 | 5.1 | 6.2 | 6.7 | 5.9 | .921 | <.001 | .073 | .045 |
| Vitamin C, mg | 88 | 98 | 105 | 96 | .003 | 70 | 86 | 101 | 107 | .002 | .139 | .002 | .843 |
| Thiamine, mg | 1.2 | 1.3 | 1.1 | 1.0 | .006 | 1.0 | 1.4 | 1.3 | 1.1 | .003 | .028 | <.001 | .009 |
| Folate, μg | 259 | 258 | 236 | 223 | .029 | 192 | 247 | 252 | 216 | .349 | .390 | .099 | .046 |
| Calcium, mg | 991 | 939 | 901 | 915 | .046 | 1030 | 1140 | 1194 | 1103 | .799 | <.001 | .728 | .124 |
| Iron, mg | 10.3 | 10.7 | 9.7 | 9.0 | .061 | 7.4 | 9.5 | 9.5 | 8.0 | .046 | .005 | .003 | .026 |
| Zinc, mg | 11.2 | 11.0 | 10.1 | 9.3 | .001 | 8.5 | 1 | 10.3 | 9.0 | .023 | .241 | .004 | .003 |
| Magnesium, mg | 327 | 335 | 308 | 293 | .051 | 270 | 324 | 314 | 287 | .127 | .751 | .016 | .071 |

BW, body weight; MUFA, monounsaturated fatty acid; NMES, nonmilk extract sugars; PUFA, polyunsaturated fatty acid; Q, quartile; SFA, saturated fatty acid.
Statistical significance for hypotheses of linearity was evaluated by analysis of variance (ANOVA): *adjusted with weight, †age- and sex-adjusted.

University of Helsinki (NC) or by the Helsinki University Central Hospital Ethics Committee (HBS, PSNT, and ALF).

## Results

The energy range, mean E%, and amounts (g) for the NMES quartiles were classified as follows: Q1 = 0–6.9 E%; mean 5 E% (19.4 g), Q2 = 7–9.7 E%; mean 8 E% (35.6 g), Q3 = 9.8–15.1 E%; mean 12 E% (51.2 g), and Q4 = 15.2–38.0 E%; mean 21 E% (87 g) (Tables 1 and 2). Participants with low NMES intake (Q1 and Q2) were younger and more likely to be males than those with high NMES intake ($P < .001$). The body mass index (BMI) and MNA scores decreased with increasing intake of NMES ($P < .001$). Furthermore, high NMES intake was associated with poor cognition, immobility, and institutionalization; in fact, of those in the highest NMES intake quartile (Q4), 90% were institutionalized and 71% suffered from moderate or severe dementia as measured by the CDR.

The institutionalized participants consumed diets higher in NMES than did those living at home. Most home-dwelling participants showed low to moderate intake of NMES, whereas more than half of those in institutions were placed in the highest NMES quartile (Q4). Furthermore, the energy and nutrient intakes in the NMES quartiles differed between home-dwelling and institutionalized individuals. In the former, most nutrient intakes declined linearly as the E% received from NMES increased (Table 2). In the latter, most nutrient intakes were lowest in either the lowest NMES quartile (Q1), where the energy intake was low (1314 kcal), or in the highest NMES quartile (Q4). In contrast to other nutrients, carbohydrates and vitamin C were highest in the highest NMES quartile (Q4) in the institutionalized participants.

There was interaction between the place of residence and E% of NMES; thus, the place of residence affected the association of nutrient intakes in the NMES quartiles (Table 2).

## Discussion

High NMES intake was associated with older age, low MNA scores, immobility, and poor cognition. The institutionalized participants consumed diets higher in NMES than did those living at home. The protein and most nutrient intakes of home-dwelling participants declined linearly as the E% from NMES increased, whereas the protein and other nutrient intakes were generally lowest in institutionalized participants in both the lowest and highest NMES quartiles.

The strength of this study is its large sample size, because of combining data from various nutritional studies representing the heterogeneity of older people, from institutionalized residents to healthy independent individuals. Furthermore, all the nutritional studies used similar data-gathering methods, making it possible to combine the data in a single set.

The main limitation of our study was the inability to distinguish the added sugars from naturally occurring sugar in plant sources, that is, vegetables and fruits. This was due to the limitations of the programs used to analyze the food records. The institutionalized participants in the highest NMES quartile (Q4) consumed the highest amounts of vitamin C, compared with those in the other quartiles. The higher vitamin C intakes could have been due to the consumption of sugar-sweetened beverages that were fortified with vitamin C or to the abundant intake of naturally vitamin C–containing fruit juices.[20] The abundant intake of fruits and vegetables would most likely also have had an increasing effect on the other nutrient intakes, such as folate and fiber, which were lowest in the highest NMES intake quartile. Because of the cross-sectional nature of this study, causal relationships cannot be drawn from the results.

In our sample of older people, considerable differences in NMES consumption were observed. Those with the poorest cognition and

who were living in institutions showed the highest NMES intake. Some studies have suggested that patients with AD may have increased preference for sweet-tasting foods.[21] Because 71% of those in the highest NMES quartile had either moderate or severe dementia, the preference for sweet-tasting foods may partly explain the increased sugar intake in the most vulnerable older population found in our study. The protein intake was lowest in the highest NMES quartile among the home-dwelling participants, whereas those in institutions and in both the lowest and highest NMES quartiles showed poor protein intakes. Displacement of protein-rich foods by sugar in the diets of the most vulnerable older people who do not meet the protein recommendations may have important implications for the health and functioning of individuals at risk of frailty.[22]

Low energy intake in older people is a common occurrence, especially in those in institutions, and is a known risk factor for inadequate nutrient intake.[13] An energy intake of 1500 kcal is considered to be the minimum amount needed for receiving all the essential nutrients from the diet.[23] Although there were very small numbers of participants ($n = 20$) in the NMES (Q1), their mean energy intake was only 1314 kcal, which is clearly insufficient to satisfy essential nutrient needs. Therefore, the protein and most nutrient intakes were also lowest in this quartile. On the other hand, more than half of the institutionalized participants were placed in the highest NMES quartile (Q4), which also showed low mean protein and micronutrient intakes. This group seems to be more problematic, because of the high number of participants placed in this group, than those in Q1, to which only a very small proportion of institutionalized participants were assigned. In contrast to the institutionalized participants, there were no differences in energy intakes between the NMES quartiles in the home-dwelling participants. The protein and micronutrient intake declined linearly as the E% received from NMES increased. As seen in the interaction test, the place of residence substantially affected the E% received from NMES and the nutrient intakes in our sample of older people. Multiple testing as performed in the interaction test can cause bias, thus giving false significant *P* values. However, because the interaction test gave similar results in most nutrients, it seems safe to assume that the figures are correct.

The possible adverse health effects of high sugar intake have been widely discussed during recent years. The WHO recommends a sugar intake of $<10$ E% and has recently issued a conditional recommendation for further reduction of sugar to 5 E%.[1] The WHO guidelines do not refer to the natural sugars present in fresh fruits, vegetables, and milk products, because there is no reported evidence of adverse effects of consuming naturally occurring sugars.[1] The scientific evidence for reducing sugar intake is mainly due to the increase in obesity in association with high sugar intake in adults and children.[24] Although the added sugar intake was not directly comparable with the NMES intakes, the BMIs in our sample tended to decrease with higher NMES intakes. Thus, in vulnerable older people the main nutritional risk of high sugar intake is more likely to be associated with low diet quality and poor protein and micronutrient intakes, rather than an increase in obesity.[4]

The evidence for micronutrient dilution in association with high sugar intakes has been conflicting. In two systematic reviews, no clear evidence for micronutrient dilution was noted.[3,7] Few studies have examined nutrient dilution with diets high in sugars in older people.[4–6] The definition of sugars has varied depending on the study, which makes comparison difficult. In a study by Gibson et al,[6] moderately high NMES intakes of up to 15 E% were unlikely to have caused micronutrient dilution in independent older people. On the other hand, high added sugar intake caused micronutrient dilution in older South African women and Australians.[4,5]

## Conclusion

In our sample of both home-dwelling and institutionalized older people, a high E% of NMES was associated with protein, fat, micronutrient, and fiber dilution, although only minor proportions of home-dwelling participants were in the highest NMES quartile. In institutionalized participants, both low energy and high NMES intakes seem to be problematic. The sugar contents of the foods served in home care and service house settings should be reduced and greater emphasis placed on the overall diet quality of the foods served. On the other hand, it is important to consider that some of the most vulnerable older people, for example, those with AD, may themselves limit their food consumption and prefer high sugar-containing foods. Healthy, tasty, nutrient-dense foods and snacks for the most vulnerable older people should be developed.

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